

AD-A241 944

INTRODUCTION PAGE

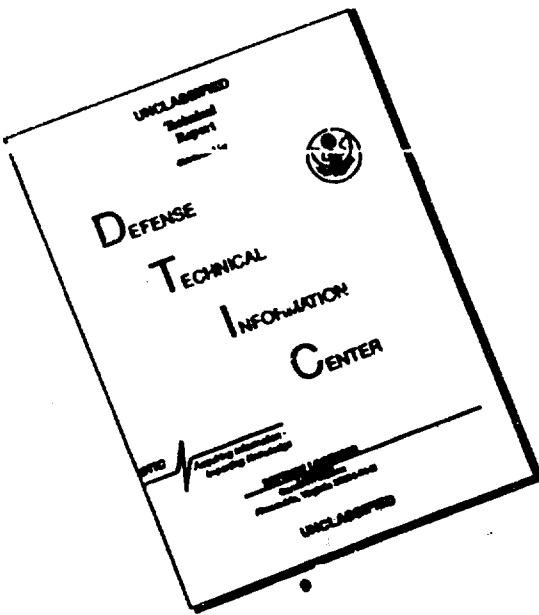
Form Approved
OMB No. 0704-0188

Q

Estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Place, Washington, DC 20503.

| | | |
|---|--|--|
| 1. SUBJECT | 2. REPORT DATE | 3. REPORT TYPE AND DATES COVERED |
| | 9/17/91 | Final, April 1-September 17, 1991 |
| 4. TITLE AND SUBTITLE | | 5. FUNDING NUMBERS |
| 1991 Gordon Research Conference on Physical Metallurgy | | G-AFOSR-91-0173 |
| 6. AUTHOR(S) | | |
| Alexander M. Cruickshank and John H. Perepezko | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) | | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| Gordon Research Conferences, Incorporated University of Rhode Island Kingston, RI 02881-0811 | | 0876 |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER |
| AFOSR/NE Building 410 Bolling AFB, DC 20332-6448 | | DTIC ELECTED OCT 23 1991 S-100 |
| 11. SUPPLEMENTARY NOTES | | |
| Prepared in collaboration with Dr. W. J. Boettinger | | |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT | | DISTRIBUTION CODE |
| Unlimited | | 91-13732 |
| 13. ABSTRACT (Maximum 200 words) | | |
| <p>The 1991 Gordon Research Conference on Physical Metallurgy was held July 29-August 2, 1991 at the Plymouth College South location in Plymouth, New Hampshire. The Conference topic was Foundations of Microstructure Development. The study of microstructural development in metals and alloys is a cornerstone of physical metallurgy. From an understanding of the compositional, thermodynamic and kinetic constraints, new levels of control and the development of new microstructures may be possible. The discussion was organized to present state-of-the-art developments in such keynote issues as alloy phase stability, crystal growth and solidification, diffusion in ordered alloys and multicomponent systems, interfacial structure and phase decomposition kinetics. There was a balanced coverage between theoretical and modeling analysis and critical experimental work involving verification tests and applications. In addition, an industrial perspective in the areas of aluminum alloys, aerospace materials and electronic materials was included in the program.</p> <p>In light of the vigorous discussion during the conference the foundations of microstructural development clearly generated a keen interest. Several emerging new issues in alloy phase stability, in crystal growth and solidification, diffusional reactions, interfacial structure and phase decomposition were highlighted during the meeting. Equally important is the industrial perspective that allowed for the often pointed out gap between theoretical and experimental developments and industrial applications to be bridged to some extent. New perspectives and new interactions were developed at the meeting which will yield future dividends.</p> | | |
| 14. SUBJECT TERMS | | 15. NUMBER OF PAGES |
| Gordon Research Conference, Physical Metallurgy, Phase Transformations, Solidification, Interfaces, Diffusion, Elastic Strain, Ordered Alloys, Phase Equilibria | | |
| 16. PRICE CODE | | |
| 17. SECURITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT |
| | | 20. LIMITATION OF ABSTRACT |

DISCLAIMER NOTICE



**THIS DOCUMENT IS BEST
QUALITY AVAILABLE. THE COPY
FURNISHED TO DTIC CONTAINED
A SIGNIFICANT NUMBER OF
PAGES WHICH DO NOT
REPRODUCE LEGIBLY.**

FINAL REPORT

AFOSR Grant (AFOSR-91-0173) for the Support of the 1991 Gordon Conference on Physical Metallurgy

"Foundations of Microstructure Development"

Submitted to

Air Force Office of Scientific Research
Division of Research Grants, Building 410
Bolling AFB, Washington, DC 20332-6448

Attention: Dr. Alan H. Rosenstein

Submitted by

Dr. John H. Perepezko (Co-Chairman and P.I.)
Professor, Department of Materials Science and Engineering
University of Wisconsin-Madison
1509 University Avenue
Madison, WI 53706

Dr. William J. Boettinger
National Institute of Standards and Technology
Metallurgy Division
Building 223 Room A153

and

Dr. Alexander M. Cruickshank (Director)
Gordon Research Conferences
University of Rhode Island
Kingston, RI 02881

| | |
|--|---------------|
| Approved for Release Under the Freedom of Information Act | NTIS CR-341 |
| DTIC Type | Unnumbered |
| Distribution | Justification |
| Comments | Comments |
| Dist | Dist |
| A-1 | |

Approved for public release
Distribution unlimited

Introduction

The 1991 Gordon Research Conference on Physical Metallurgy was held July 29-August 2, 1991 at the Plymouth College South location in Plymouth, New Hampshire. The Conference topic was Foundations of Microstructure Development. US Government grants were made to the Gordon Research Conference to offset partially the travel and registration cost of many the speakers and discussion leaders, a few attendees, and the co-chairman. Grants totaled \$18,000.00. Of this total, \$6,000.00 each was provided by AFOSR (AFOSR-91-0173), ONR and NSF (DMR-9102779). In this final report a brief description of the conference is given and includes some of the highlights of the meeting and discussions.

Conference Description

The study of microstructural development in metals and alloys is a cornerstone of physical metallurgy. An effective approach to this theme can be developed by examining the limiting bounds for a given microstructural type. From an understanding of the compositional, thermodynamic and kinetic constraints, new levels of control and the development of new microstructures may be possible. As a result, the conference program was focused on the critical processes governing microstructural development. The discussion was organized to present state-of-the art developments in such keynote issues as alloy phase stability, crystal growth and solidification, diffusion in ordered alloys and multicomponent systems, interfacial structure and phase

decomposition kinetics. There was a balanced coverage between theoretical and modeling analysis and critical experimental work involving verification tests and applications.

The conference program was organized on the basis of the realization that major advances in physical metallurgy leading to novel insight or new discoveries have often occurred as a result of a steady, concerted study effort on an experimental and theoretical front to examine fundamental physical processes. Often the discoveries appear as anomalies, but with further examination the anomaly becomes recognized as a new aspect of a basic mechanism. In addition, there is an important realization that much of the work in the physical metallurgy of advanced materials is intended for eventual applications. As a result, the initial session of the first day provided that perspective in the areas of aluminum alloys, aerospace materials, and electronic materials. This was followed by a session on interface reactions where the theoretical and experimental developments including the latest studies were described. Since most metals undergo a melting and solidification process sometime during their fabrication, the importance of crystal growth and solidification is apparent and occupied most of the discussion of the second day. Similarly, the basis of materials processing is rooted in diffusional transformations which was the basic theme of the third day where the discussion ranged from the very early stages of precipitation to multicomponent systems and basic mechanisms of diffusion in more complex systems. This discussion carried over to the fourth day with some of the detailed studies of

interface structure including the effects of elastic stresses. Finally, the program ended with discussion of ordering reactions and displacive transformation that are becoming recognized as crucial in many of the latest developments in transformation kinetics.

While every effort was made to identify frontier issues with each of the foundation topics, it was recognized that such a listing can not be completely comprehensive and still allow time for the extensive discussion that is the hallmark of a successful Gordon Conference. Certainly, further issues and perspectives were brought out in the discussion. However, each of the foundation topics could be a theme of a separate conference. Indeed one of the advantageous of the Gordon Conference forum is the ability to bring together various groups and perspectives to have a high level exchange of experimental and theoretical developments.

Following the tradition of previous Gordon Conferences, a relatively small number of speakers were invited to make presentations to the conference. The main purpose of these talks was to describe recent progress and set the stage for further thought and discussion. A copy of the program and speakers and discussion leaders is appended to this report. In addition, a poster session was also held during the conference in order to allow some of the participants to present their research results. This was a well attended session with over 20 contributed

posters, provided a basis for broad exposure of very new results and stimulated a great deal of excitement that are often continued late into the evening.

The conference attracted participants from a wide variety of institutions and backgrounds. A list of attendees appended to this report shows that a total of 124 scientists and engineers participated in the conference. Of these only 31 were on the program as speakers and discussion leaders. The attendees included 106 from the United States and 18 from foreign countries. Of these 68 were from universities, 37 from government laboratories or offices and 19 from industry. Finally it is worth noting that the number of applicants for this conference exceeded the number of places available.

Program Highlights

The major attraction at Gordon Conferences is the opportunity to interact on an informal level with a large number of scientists interested and knowledgeable in a given subject. Facilities at the Plymouth College catered to this aspect in a number of ways; the main lounge, the game room, and the grounds were excellent sites for informal discussion. These facilities were in use throughout the day and night for numerous small group discussions which led to the development of research ideas and interactions. This informal aspect of the Gordon Conference, was therefore a success.

In the formal program the initial session provided an industrial perspective on advanced materials. For example, Staley from Alcoa discussed aluminum alloy development and as

requested raised a number of issues for future work including how the grain size is limited by various particles in aluminum alloys, some new areas in presolidification processing to initiate particulate formation, and the need for additives in aluminum alloys to remove undesirable impurities. In a similar vein Blackburn from Pratt & Whitney discussed the importance of modeling in scaling-up processing from laboratory operations to production operations. He also pointed out that the best property in any given category cannot usually be obtained in the best combination of properties and as a result process models are essential to allow for an optimum balance of properties. Rosenberg from IBM provided information on many exciting developments in the miniaturization of electronic circuits down to 0.1 microns in scale. Devices have been made in the laboratory, but again the point was made on how to scale-up the processing. He pointed out that more than 98% of system failures are related to metallization treatments and that this issue provides a wealth of important problems to deal with. Next, John Cahn provided an informative discussion of heterogeneous nucleation along the lines of Gibbs including very interesting new developments in wetting behavior and crystal morphologies. This discussion was complemented very nicely by Dahmen who provided some outstanding TEM micrographs to illustrate the development of crystal morphology at the atomic scale. The next day was devoted to solidification. Trivedi gave an overview of some of the unsolved problems in solidification microstructure development. He also provided useful insight into the

understanding of study state processes and the development of microstructure over a range of velocity. Brown followed this with a more focused discussion on wavelength selection during cellular solidification where the complete domain of velocity-wavelength behavior is being mapped out including the important onset ranges of breakdown of planar interface and the various time scales appropriate for the different breakdown behavior. Dantzig gave summary of the modeling approaches to process development ranging from nucleation kinetics models, which are sorely lacking to approaches for accounting for growth kinetics and heat evolution during solidification. The evening session belonged to the theoreticians. Sekerka provided very effective introduction to the main theoretical developments in diffuse interface theories of crystal growth and phase field calculations of solidification. These are two approaches to deal the difficulties of matching solutions in the liquid and solid state at the interface. In the diffuse interface model Oxtoby described perturbation approaches where the liquid is treated as a perturbed solid and the solid treated as a perturbed liquid as a means of modeling their behavior. Wheeler approached the problem from phase field model method which deals with the existence of various potentials which are expressed in terms of an order parameter. While each approach has advantages, it is not clear at present which is superior. They both appear to give effective descriptions of observed behavior. Clearly more development of analysis is needed. On the third day Cohen provided an excellent overview of the early stages of

participation including the formation of GP zones, initially ordered configurations and clustering effects where strain energy factors become important. This is followed Purdy's discussion of precipitation in ternary systems where the concept of local equilibrium sometimes needs to be modified to include paraequilibrium i.e. equilibrium with respect to one component. The morning ended with a discussion by Greer of recent developments in solid state amorphization during interdiffusion reactions. The various thermodynamic and kinetic behaviors were analyzed including how to treat diffusion in the very steep concentration gradients that develop in multilayer structures at the onset of interdiffusion which is a new realization.

These discussions were followed in the evening by a presentation on diffusion in ordered alloys by Bakker who pointed out that there is a much stronger correlation factor in ordered crystals than in disordered crystals and that one must consider defect structures on the sublattices in ordered crystals. For example, when this is done in Ni₃Al, it is found that nickel can diffuse on its own sublattice at much the same rate as for self diffusion in pure nickel. Van Loo presented an elegant discussion of the Kirkendall effect during multiphase diffusion. He described methods to analyze diffusion path sequences in multicomponent systems which is crucial in the development of composite structures. The importance of interfaces and domain structures that develop in elastically strained systems was the highlight in the next session. Howe presented video images of lattice resolution TEM studies conducted at high temperature to

reveal the dynamics of interface motion. This is truly a remarkable experimental achievement. Voorhees discussed an interesting analysis of the competition between strain energy and interfacial energy in determining the equilibrium shape of a precipitate in the later stages of reaction. Roytburd followed with a detailed analysis of the formation and development of polydomain structures that often occur in twinning and martensite reactions and involve multiple subdivision with the development of increasing levels of elastic strain. The last two sessions dealt with various aspects of the thermodynamics and kinetics of ordering reactions. Inden gave an informative overview of phase diagram modeling starting from the regular solution all the way up to cluster variation methods that are used to treat more complex interactions. This is followed by Allen's analysis of the behavior of diffuse interfaces with respect to order parameter as well as concentration gradients. He applied this analysis to explain some of the domain coarsening kinetics observed in ordered alloy. In a detailed study of the kinetics of ordering reactions, Banerjee highlighted some of the crystallographic aspects. Often BCC phases develop transformations by various shears of (110) planes. In the last presentation Johnson tried to integrate the diffusive and displacive characteristics of transformations. It is becoming clear that both aspects can occur in given transformation types and that the traditional distinction between displacive and diffusional transformations is not as sharp as it has been viewed previously. As a sign of the interest and animated discussion

during the conference, it is useful to point out that more than 85 people were on hand to hear the last presentation on Friday morning.

In light of the vigorous discussion, the foundations of microstructural development clearly generated a keen interest. Several emerging new issues in alloy phase stability, in crystal growth and solidification, diffusional reactions, interfacial structure and phase decomposition were highlighted during the meeting. Equally important is the industrial perspective that allowed for the often pointed out gap between theoretical and experimental developments and industrial applications to be bridged to some extent. New perspectives and new interactions were developed at the meeting which will yield future dividends.

**Physical Metallurgy
Gordon Conference**
Plymouth State College (South), Plymouth, NH
July 29 - August 2, 1991

William J. Boettiger and John H. Perepezko, Cochairmen
Anthony W. Thompson and Robert O. Ritchie, Vice-Cochairmen

1991 Conference Topic Foundations of Microstructure Development

Morning sessions start at 8:30 AM
Evening sessions start at 7:30 PM

Monday AM: Industrial Perspective on Advanced Materials (Alan Rosenstein, AFOSR)

Monday PM: Interface Reactions (Frans Spaepen, Harvard)

Tuesday AM: Solidification Microstructures (John Hunt, U. of Oxford)

| | |
|---|---|
| Rohit Trivedi, Iowa State U. Robert Brown, MIT | Solidification Microstructures Nonlinear Dynamics & Wavelength Selection in Cellular Solidification |
| Jonathan Dantzig, U. of Illinois-Urbana | Macro/Micromodelling of Eutectic Castings |

Tuesday PM: Crystal Growth Kinetics (Bob Sekerka, Carnegie-Mellon)

David Oxtoby, U. of Chicago
Adam Wheeler, U. of Bristol

Diffuse Interface Theories of Crystal Growth
Phase Field Calculations of Binary Alloy
Solidification

Wednesday AM: Diffusional Transformations (Bill Morris, UC-Berkeley)

Jerry Cohen, Northwestern U.
Gary Purdy, McMaster U.
Lindsay Greer, U. of Cambridge

Early Stages of Precipitation
Precipitation in Ternary Systems
Solid-State Amorphization

Wednesday PM: Diffusion Mechanisms (John Morral, U. Conn.)

Hans Bakker, U. Amsterdam Diffusion Mechanisms in Ordered Intermetallics
Frans van Loo, Eindhoven U. Kirkendall Effect in Multiphase Diffusion

Thursday AM: Interfaces & Domains (Caroi Handwerker, NIST)

| | |
|------------------------------------|---|
| Jim Howe, U. of Virginia | HRTEM of Interfaces |
| Peter Voorhees, Northwestern U. | Dynamics of Interfaces in Elastically Stressed Solids |
| Alexander Roytburd, U. of Maryland | Formation of Polydomain Structures |

Thursday PM: Ordering Transformations (Ben Burton, NIST)

| | |
|---|--|
| Gerhard Inden, Max Planck Inst. Eisenforschung | Phase diagram Modeling |
| Sam Allen, MIT | Diffuse Interfaces in Ordering Systems |

Friday AM: Displacive Transformations (Lee Tanner, Lawrence Livermore)

| | |
|--|--|
| Srikumar Banerjee, Bhabha Atomic Research Centre, Bombay, India | Replacive/Displacive Ordering |
| Bill Johnson, Carnegie-Mellon | Transformations Displaying Diffusive and Displacive Characteristics |

GORDON RESEARCH CONFERENCE
Physical Metallurgy

Registration List
July 29 - August 2, 1991
Plymouth State College, Plymouth, NH

| | | | |
|---|------|--|-----|
| Dr. Ralph Adler | 626 | Dr. Michael Baskes | 404 |
| Army Materials Tech. Lab. | | US Dept. of Energy | |
| SLCMT-EMM Arsenal St. | | Division of Material Sciences ER-131/GTN | |
| Watertown, MA 02172 | | Washington, DC 20585 | |
| Dr. Robert Aikin Jr. | 719 | Paxal Bellon | 606 |
| Martin Marietta Labs. | | SRMP, Centre D/Etudes de Saday | |
| 1450 South Rolling Rd. | | Elsur Yvette, France 91191 | |
| Baltimore, MD 21227 | | | |
| Dr. Donald Robert Allen | 511 | Dr. Leonid Bendersky | 304 |
| University of Wisconsin | | NIST, Metallurgy Div. BLDG 223,A-155 | |
| Dept. of Materials Sci. & Engineering | | Gaithersburg, MD 20899 | |
| 1509 University Ave. | | | |
| Madison, WI 53706 | | | |
| Dr. Samuel Allen | 513 | Dr. Martin J. Blackburn | 325 |
| Massachusetts Institute of Technology | | Pratt & Whitney | |
| RM. 13-5056 77 Massachusetts Ave. | | Materials Engin. Mail Stop 114-43 | |
| Cambridge, MA 02139 | | 400 Main Street | |
| Agren | 623 | E. Hartford, CT 06108 | |
| Division of Physical Metallurgy | | | |
| Royal Inst. Technology | | | |
| S-100 44 Stockholm, Sweden | | | |
| Dr. Iver Anderson | 713 | Dr. William Boettinger | 509 |
| Ames Lab. & Iowa State University | | NIST, A153-Bldg. 223 | |
| 122 Metals Development BLDG. | | Gaithersburg, MD 20899 | |
| Ames, IA 50011 | | | |
| Alan Ardell | O.C. | Richard Braun | 504 |
| University of California | | Dept. of Engineering Sciences | |
| Dept. of Materials Science & Engineering | | Technological Inst. Northwestern Univ. | |
| 5732-J BH Los Angeles, CA 90024-1595 | | Evanston, IL 60208 | |
| Dr. Harry Atwater | 622 | Yves Brechet | 302 |
| Caltech, MS 128-95 | | CR. Pechiney, 38000 Vorteppre | |
| Pasadena, CA 91125 | | France | |
| Dr. Michael Aziz | 526 | Manfred Breiter | 622 |
| Harvard University | | Inst. Techn. Elektrochem | |
| Division of Applied Sciences, 29 Oxford St. | | 9 Getreidemarkt | |
| Cambridge, MA 02138 | | Wien, Austria 1060 | |
| Dr. Hans Bakker | 623 | Dr. John Brooks | 621 |
| University of Amsterdam | | Sandia National Labs. 312 | |
| Valckenierstr. 65 | | Livermore, CA 94550 | |
| Amsterdam, The Netherlands NL1018XE | | | |
| Dr. Srikumar Banerjee | 326 | William Brower Jr. | 621 |
| Bhabha Atomic Research Center | | Marquette University | |
| Metallurgy Div. Bombay, India 400 085 | | Dept. of Mech. & Indust. Engineer. | |
| | | 1515 W. Wisconsin Ave. | |
| | | Milwaukee, WI 53233 | |
| | | Dr. Robert Brown | 324 |
| | | Massachusetts Institute of Technology | |
| | | Chemical Engineering Dept. 66-342 | |
| | | Cambridge, MA 02139 | |

| | | | |
|---|-----|---|------|
| Dr. Lucien Brush University of Washington Dept. of Materials Sci. & Engin. 325 Robers Hall FB-10 Seattle, WA 98195 | 323 | Dr. James Dela'O Michigan Technological University Metallurgical Materials Eng. Dept. Houghton, MI 49931 | 617 |
| Dr. Benjamin Burton NIST, A153/223 Gaithersburg, MD 20899 | 519 | Larry DeVries MEB 2220 University of Utah Salt Lake City, Utah 84112 | O.C. |
| Dr. Daniel Butrymowicz National Institutes of Standards & Techn. Materials Bldg., RM B309 Materials Science & Engineering Lab. Gaithersburg, MD 20899 | 710 | Dr. James Early National Institutes Of Standards Materials Bldg., Rm B309 Materials Science & Engineering Lab. Gaithersburg, MD 20899 | 220 |
| Dr. John Cahn NIST, 223/A153 Gaithersburg, MD 20899 | 222 | Dr. John Elmer Lawrence Livermore National Lab. PO Box 808, L355 Livermore, CA 94551 | 617 |
| Dr. Ray Carpenter Center for Solid State Science Arizona State University Tempe, Arizona 85287-1704 | 405 | Dr. Paul Evans Alcan International Banbury Lab., Southam Rd. Banbury, Oxon, England OX 16 7SP | 219 |
| Dr. William Cassada III Reynolds Metals Company Corporate Research & Development 4th & Canal St. Richmond, VA 23229 | 717 | Dr. Harold Frost Dartmouth College Thayer School of Engineering Hanover, NH 03755 | 611 |
| Dr. Long-Qing Chen Rutgers University Dept. of Matl. Sci., PO Box 909 Piscataway, NJ 08855-0909 | 620 | Pro. Hans Fecht University of Augsburg Inst. of Physics Memmingerstr. 6 8900 Augsburg Germany | 721 |
| Dr. Jerome Cohen Northwestern University McCormick School of Engineering Evanston, IL 60208 | 619 | Dr. Steven Fishman Office of Naval Research 800 N. Quincy St. Arlington, VA 22217 | 217 |
| Dr. Ulrich Dahmen National Ctr. for Electron Microscopy Lawrence Berkeley Lab, BLDG. 72 1 Cyclotron Rd. Berkeley, CA 94720 | 221 | Peter Frankwicz University of Wisconsin Dept. of Materials Sci. & Engin. 1509 University Ave. Madison, WI 53706 | 511 |
| Dr. Jonathan Dantzig University of Illinois Dept. of Mechanical & Industrial Engrg. 1206 West Green St. Urbana, IL 61801 | 619 | Dr. Frank Gayle NIST, RM 223/A153 Gaithersburg, MD 20899 | 519 |
| Dr. Siddhartha Das University of Wisconsin-Madison Dept. of Materials, Science & Eng. 1509 University Ave. Madison, WI 53706 | 507 | Dr. Uwe Glatzel Stanford University Dept. of Materials Science & Engin. TU-Berlin, BH18, 7000 Berlin 12 FRG Stanford, CA 94305-2205 | 626 |

| | | | |
|--|------|--|-----|
| Dr. Rolf Gotthardt Ecole Polytechnique Federale Lausanne Lausanne, Switzerland CH-1015 | 406 | Dr. Bimal Kad Ohio State University 116 W. 19th Ave. Columbus OH 43210 | 607 |
| Dr. Douglas Granger Alcoa Lab., Alcoa Technical Center Alcoa Center, PA 15069 | 407 | Mike Kaufman University of Florida 201 Rhines Hall Dept. of Materials Science & Engr. Gainesville, FL 32611 | 502 |
| Dr. A Greer University of Cambridge Dept. of Materials Science & Metallurgy Pembroke St. Cambridge, UK CB2 2QZ | 211 | Pro. Ryoichi Kikuchi University of California, Los Angeles Materials Science & Engineering Los Angeles, CA 90024-1595 | 408 |
| Dr. Amitava Guha Brush Wellman Inc. 17876 St. Clair Ave. Cleveland, OH 44110 | 209 | Dr. Carl Koch North Carolina State University Materials Science & Eng. Depc. PO Box 7907 Raleigh, NC 27695 | 321 |
| Dr. Carol Handwerker NIST, 233/A153 Gaithersburg, MD 20899 | 0.C. | Dr. David Lee USAF, Materials Directorate, WL/MLM WPAFB, OH 45433 | 411 |
| Dr. Stewart Harris SUNY, CEAS Stony Brook, NY 11794 | 611 | David Y. Lee Materials Sci. & Engin. Postech Pohang, Korea 790-600 | 613 |
| David Hoglund Harvard University Gordon McKay LB 9 Oxford Street Cambridge, MA 02138 | 608 | Richard Lewis LMSC Inc., 93-10/204 3251 Hanover St. Palo Alto, CA 94304 | 502 |
| Dr. William Hopfe University of Connecticut Box U-136, Dept. of Metallurgy Storrs, CT 06269-3136 | 608 | Dr. Harry Lipsitt Wright State University Dept. of Mech. & Mats. Eng. Dayton, OH 45435 | 420 |
| Dr. James Howe University of Virginia Dept. of Materials Science, Thornton Hall Charlottesville, VA 22902-2442 | 208 | Dr. A Loiseau ONERA, 29 Ave. DE LA Division Leclerc BP 72 Chatillon France 92322 | 320 |
| Dr. J D Hunt University of Oxford Dept. of Materials, Parks Rd. Oxford, United Kingdom OX1 3PH | 0.C. | Dr. Blair London Howmet Corp. 1500 S. Warner St. Whitehall, MI 49461-1895 | 409 |
| Dr. Gerhard Inden Max-Planck-Institut Eisenforschung Max-Planck-Str. 1 Dusseldorf Germany | 206 | Dr. David Luzzi University of Pennsylvania Dept. of Materials Science 3231 Walnut St. Philadelphia, PA 19104-6272 | 426 |
| Dr. Mel Jackson General Electric CRD, K-1 MB 223 Box 8 Schenectady, NY 12301 | 205 | Dr. Steven Marsh Naval Research Lab. Code 6325 Washington, DC 20375-5000 | 607 |
| Dr. William Johnson Carnegie Mellon University 3325 Wean Hall Pittsburgh, PA 15213-3890 | 505 | | |

| | | | |
|--|-----|--|-----|
| Dr. Patrick Martin | 319 | Dr. Tai Nguyen | 605 |
| Rockwell International Science Center | | LBL/UC Berkeley | |
| 1049 Camino Dos Rios | | Lawrence Berkeley Lab. | |
| Thousand Oaks, CA 91360 | | MS 2-400, 1 Cyclotron Rd. | |
| | | Berkeley, CA 94720 | |
| Dr. Carolyn MacDonald | 418 | Dr. Ben Oliver | 605 |
| SUNY Albany, Physics Dept. | | University of Tennessee | |
| Albany, NY 12222 | | Dept. of Materials Science & Engin. | |
| Dr. Bruce MacDonald | 225 | RM 425, Dougherty Engineering Bldg. | |
| National Science Foundation | | Knoxville, TN 37996-2200 | |
| Div. of Material Research 6800 G. St. | | | |
| Washington, DC 20550 | | | |
| Dr. Arthur McEvily | 313 | Dr. David Oxtaby | 317 |
| University of Connecticut | | University of Sydney | |
| Metalurgy Dept., U-136 | | Dept. of Theoretical Chemistry | |
| Storrs, CT 06268 | | Sydney, Australia NSW 2006 | |
| Dr. CJ McMahon Jr. | 415 | Dr. John Perepezko | 509 |
| University of Pennsylvania | | University of Wisconsin | |
| Dept. of MSE, 3231 Walnut St. | | Dept. of Mat. Sci. & Eng. | |
| Philadelphia, PA 19104 | | 1509 Univ. Ave. | |
| Dr. Mark McCormack | 625 | Madison, WI 53706 | |
| Lawrence Berkaley Lab/UCB | | | |
| #1 Cyclotron Rd. MS 66-200 | | | |
| Center For Advance Material/MS&ME | | | |
| Berkaley, CA 94720 | | | |
| Dr. Jyothi Menon | 410 | Kevin Peters | 511 |
| Wright Patterson Air Force Base | | Dept. of Materials Science | |
| WL, MELM | | Evanston, IL 60202 | |
| Wright-Patterson A, OH 45433-6533 | | | |
| Dr. John Morral | 606 | Dr. Jean Philibert | 311 |
| University of Connecticut | | Universite Paris -SUD | |
| 97 N. Eagleville Rd., RM 111 | | Metallurgie - BAT 413 | |
| Storrs, CT 06269-3136 | | Orsay France F-91405 | |
| Dr. James Morris | 606 | Dr. David Pope | 603 |
| University of Kentucky | | University of Pennsylvania | |
| Light Materials Research Labs. | | MEAM Dept. Towne Bldg. | |
| Anderson Hall | | 220 S. 33rd St. | |
| Lexington, KY 40506 | | Philadelphia, PA 19104-6315 | |
| Dr. John Morris Jr. | 625 | Dr. Gary Purdy | 424 |
| University of California, Berkeley | | McMaster University 1280 Main St. West | |
| One Cyclotron Rd. MS 66-800 | | Materials Science & Engineering | |
| Center for Advance Materials/MS&ME | | Hamilton, Ontario, Canada L8S 4L7 | |
| Berkaley, CA 94720 | | | |
| Dr. Dongkyu Na | 521 | Dr. James Rawers | 310 |
| Northwestern University | | US Bureau of Mines | |
| Tech. Inst. of Materials Sci. & Engin. | | Albany Research Center | |
| 2145 Sheridan | | 1450 SW Queens Ave. | |
| Evanston, IL 60201 | | Albany, Oregon 97333 | |
| | | | |
| | | Steven H. Reichman | 309 |
| | | Wyman-Gordon, Worcester St. | |
| | | North Grafton, MA 015 | |
| | | | |
| | | Dr. Rosenberg | 308 |
| | | IBM TJ Watson Research Center | |
| | | PO Box 210 | |
| | | Yorktown Heights, NY 10598 | |

| | | | |
|---|-----|--|-----|
| Dr. Alan Rosenstein A.F.O.S.R., AFOSR/NE Bldg. 410 Bolling AFB Washington, DC 20332 | 306 | Dr. Seiji Takeda Osaka University College of General Education Toyonaka, Osaka Japan 560 | 624 |
| Dr. Alexander Roytburd University of Maryland Materials & Nuclear Engineer. Dept. College Park, MD 20742-2115 | 304 | Dr. Lee Tanner Lawrence Livermore Nat. Lab. Chemistry & Materials Science 7000 East Ave. Livermore CA 94550 | 402 |
| Dr. Vladimir Segal Mechanical Engineering University of Delaware Newark, DE 19716 | 525 | Dr. Nagappan Thangaraj National Center for Electron Microscopy Bldg. 72 Lawrence Berkeley Lab 1 Cyclotron Rd. Berkeley, CA 94720 | 226 |
| Dr. Adam Schwartz Lawrence Livermore NL L-355 PO Box 808 Livermore, CA 94550 | 303 | Dr. Dan Thoma University of Wisconsin-Madison Dept. of Materials Science & Engin. 1509 University Ave. Madison, WI 53706 | 507 |
| Dr. Yoontto Son University of Connecticut Dept.of Metallurgy, U-136 Storrs, CT 06268 | 602 | Dr. Anthony Thompson Carnegie Mellon University Dept. of Metallurgy & Engin. Pittsburgh, PA 15213 | 604 |
| Dr. David Skinner Allied Signal Research & Technology PO Box 1021, Columbia Rd. Morristown, NJ 07962 | 602 | Dr. Ariel Traiber M.I.T. Rm 13-5126 Cambridge, MA 02139 | 604 |
| Dr. Frans Spaepen Harvard University Division of Applied Sciences 29 Oxford Street Cambridge, MA 02138 | 722 | Dr. Rohit Trivedi Iowa State University 100 Wilhelm Hall Ames, IA 50011 | 524 |
| Dr. Brian Spencer Northwestern University Dept. ES/AM Technological Inst. Evanston, IL 60208 | 504 | Dr. David Van Aken University of Michigan 2300 Hayward St. Dept.Mater Sci. & Engineering Ann Arbor, MI 48109-2136 | 508 |
| Dr. James Staley ALCOA, ALCOA Labs ALCOA Tech. Center, PA 15069 | 422 | Dr. Roy Vandermeer Naval Research Lab, Code 6320.1 4555 Overlook Ave. Washington, DC 20375-5000 | 419 |
| Dr. James Steele Jr. Los Alamos National Lab Mail Stop E506 Los Alamos, NM 87545 | 522 | Dr. Frans Van Loo Eindhoven University of Technology Lab. TVM-CTK, PO Box 513, 5600 MB Eindhoven The Netherlands | 603 |
| Dr. P R Subramanian Universal Energy Systems Inc. Materials Research Division 4401 Dayton-Kenia Road Dayton, OH 45432 | 610 | Dr. Clinton Van Siclen EG&G Idaho, Inc. Inel Research Center, Phys. & Mat. Group PO Box 1625 Idaho Falls, ID 83415-2211 | 223 |
| Dr. Bruce Taggart National Science Foundation Division of Materials Research 1800 G.St. NW Washington, DC 20550 | 624 | | |

Dr. Vijay Vasudevan 524
University of Cincinnati
Dept. of Materials Science & Engineering
ML 12 Cincinnati, OH 45221

Dr. Peter W. Voorhees 505
Northwestern University
Dept. Materials Science & Engineering
Evanston, IL 60208

Dr. David Vul 513
University of California, Berkeley
Dept. of Materials Science & Mineral Eng
Berkeley, CA 94720

Dr. John Wei 202
RES-il Timken Co.
1835 Dueber Ave. S.W.
Canton, OH 44706

Dr. Gerhard Welsch 523
Case Western Reserve University
10900 Euclid Ave.
Cleveland, OH 44106

Zhang Wenzheng 403
McMaster University
Dept. of Materials Sci & Engineering
1230 Main St. W.
Hamilton, Ontario, Canada 285 4L7

Dr. A A Wheeler 510
NIST, C/O Robin Bickel
AISI Technology NIST
Gaithersburg, MD 20899

Dr. George Yoder 204
Office of Naval Research
Materials Division, Code 1131
800N. Quincy St.
Arlington, VA 22217-5000

Dr. Frederick Yost 203
Sandia National Lab.
Dept. 1830A
Albuquerque, NM 87108

Dr. Jacob Zindel 508
Ford Motor Company
Rm S-2046 SRL
PO Box 2053
Dearborn, MI 48121-2053